

F-22 RAPTOR (ATF)



Air Force ACAT ID Program

Total Number of Systems:	339
Total Program Cost (TY\$):	\$63.4B
Average Flyaway Cost (TY\$):	\$83.6M
Full-rate production:	4QFY03

Prime Contractor

Lockheed Martin, Boeing, Pratt & Whitney

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2020

The F-22 is an air superiority fighter designed to dominate the air environment in the 21st century. Key features include low radar observability (with internal weapons carriage) and supersonic cruise combined with the classic fighter characteristics of superior maneuverability, wide field-of-regard offensive and defensive sensors, multi-spectral countermeasures, and high reliability.

Basic armament of the F-22 consists of six AIM-120C missiles, two AIM-9 missiles, and a 20mm cannon. F-22 will be a major contributor to the *Joint Vision 2020* future strategy. It is to be a predominant Air Force weapon system to provide *full-dimensional protection* to all forces, and its stealth, integrated offensive and defensive sensors, and air-to-air and air-to-ground weapons mix are to effectively support *precision engagement* and *dominant maneuver*.

BACKGROUND INFORMATION

F-22 completed the Milestone II DAB and entered the EMD phase in July 1991. Since then, the program has undergone several major changes due to schedule delays, budget reductions, and cost growth. An independent Joint Estimating Team identified significant cost growth in the EMD phase and recommended restructuring EMD. This program restructure was approved by a February 5, 1997, DAB. A primary element of this restructure was elimination of the four Pre-Production Vehicles. The essential IOT&E impact of this change was the assignment of four aircraft (4008-4011) and one spare aircraft (4007) during four ship operations. Aircraft 4010 and Aircraft 4011 are Production Representative Test Vehicles (PRTV 1) and are the performance baseline for OT test aircraft. This program restructure also increased the length of the EMD phase by nine months, allowing more time for integrated avionics testing. Dedicated IOT&E is currently scheduled to begin in August 2002, with Milestone III scheduled for September 2003.

In December 1999, the DAB delayed the planned LRIP decision and designated the next block of six aircraft as Production Representative Test Vehicles II (PRTV II). It also provided long lead-time funding for the LRIP Lot 1 of 10 aircraft and established exit criteria for the LRIP decision planned for December 2000. The test-related exit criteria are listed below:

- Complete avionics Block 3.0 first flight, initiating testing of Block 3.0 unique functionality.
- Complete first flight on EMD Aircraft 4003, 4004, 4005, and 4006.
- Complete static structural testing.
- Initiate fatigue life testing with the goal of completing 40 percent of first fatigue life.
- Conduct flight testing to include initiating Radar Cross Section (RCS) flight testing, initiating high angle-of-attack testing with weapons bay doors open, and initiating separation testing of AIM-9 and AIM-120 missiles.
- Complete first portion of engine Initial Service Release (ISR) qualification test.

The F-22 was placed under OSD oversight for LFT&E in October 1989 as the Advanced Tactical Fighter. An Alternative Plan for meeting LFT&E objectives was approved, and a waiver from full-up, system-level testing was granted with notification to Congress in August 1997. The alternate Live Fire Test (LFT) plan includes testing to determine hydrodynamic ram structural damage, dry bay fire, and critical component separation as well as demonstration of active fire suppression systems. LFT in prior years has included hydrodynamic ram vulnerability testing of wing box and aft fuel tanks, fire vulnerability testing of wing attach, aft side of fuselage, main landing gear (MLG), airframe mounted accessory drive (AMAD) dry bays, and penetration vulnerability testing of avionics bays. In addition, high explosive threat effect tests were performed to evaluate component separation adequacy. Fuselage fuel tank hydrodynamic ram damage ballistic testing is scheduled for FY01. A realistic forward fuselage test article has been manufactured for this test. Aircraft 4001 is scheduled to be used for wing fuel tank hydrodynamic ram damage and leading edge dry bay fire ballistic tests in FY01 and FY02.

TEST & EVALUATION ACTIVITY

The first flight of the EMD flight test program, Aircraft 4001, occurred on September 7, 1997, at Lockheed Martin, Marietta, GA. After being transported from Marietta, the first test aircraft resumed test flights at Edwards AFB on May 17, 1998. Aircraft 4002 first flight was on June 29, 1998, and its

ferry to Edwards AFB occurred on August 26, 1998. Both aircraft expanded the allowable flight envelope and have accumulated 797.4 hours at the end of calendar year 2000. Aircraft 4003 first flight occurred on March 6, 2000, and ferried to Edwards AFB on March 15, 2000. Following an extended modification and calibration period at Edwards AFB, this aircraft started productive flight testing on September 19, 2000, and accumulated 31.9 hours by the end of calendar year 2000.

DOT&E's activities this year continued to support test planning outlined in the August 1997 F-22 TEMP. Toward this end, DOT&E participated in Integrated Product Team (IPT) meetings of the Test Planning Working Group (TPWG), Air Combat Simulator (ACS) management reviews, IOT&E Red Force Working Group, and Working IPT (WIPT) meetings. Additional program insight was provided by visits to contractor facilities in Marietta, GA, and Seattle, WA. The Seattle visits included two Flying Test Bed (FTB) test flights. A TEMP revision is required to support the LRIP DAB. Four TEMP working group sessions were held to address 11 issues submitted by DOT&E during the West Palm Beach TPWG in January 2000. All issues have been resolved and the TEMP has been approved.

Development of the ACS, consisting of two domes and ten manned interactive cockpit stations at Marietta, GA, continued in the system development stage. A \$5.7 million budget reduction in March 1998 forced substitution of a Commercial-Off-The-Shelf computer to host F-22 mission software instead of the original plan to host the mission software portion of the aircraft's operational flight program on the Common Integrated Processor flight hardware in ACS. Restructuring ACS to accommodate this change has occurred with IOC to support IOT&E scheduled for November 2001. The ACS team moved into the new F-22 Air Vehicle Integration Facility this year and have received delivery of their first simulator dome. DOT&E reviewed ACS development plans periodically during this year to ensure that test adequacy is not being compromised by strong cost reduction pressures.

An FTB, consisting of an APG-77 radar in an F-22 forebody spliced onto the nose of a Boeing 757 test aircraft, completed the radar phase of testing early this year. After it was modified to install a sensor wing (containing some of the F-22 sensors and wing antennas) on top of the fuselage, FTB testing resumed emphasizing multi-sensor fusion of radar; Communication, Navigation, and Identification (CNI); and EW sub-systems. Block 3S software was tested against a variety of air and ground targets as a precursor to the initiation of Block 3.0 software testing on September 1, 2000—almost a month ahead of schedule. This FTB development testing of Block 3.0 software was a key part of the process leading to flying this software in Aircraft 4005. The Director, OT&E and his staff participated in a FTB Block 3.0 development mission this year, and his staff also participated in a Block 3S development mission earlier this year.

An equally important part of the avionics development process is played by the Avionics Integration Lab (AIL) at Boeing's Seattle plant. Development and troubleshooting of all software blocks have been conducted in this test facility since 1998. Block 3.1 software fusion of radar, CNI, and EW is in development testing in the AIL and will soon be installed in the FTB. The Block 3.1 software will provide the core functions of Block 3.1.1 software to be demonstrated in IOT&E. Block 3.1.1 is now starting elemental testing and will transition the AIL testing in mid-2001 and to FTB testing by late 2001.

Static structural testing has been conducted during the past two years, starting in April 1999. Testing was successfully completed to 100 percent of Design Limit Load (DLL) in 1999, and plans were to complete the ultimate load testing (150 percent of design loading) in 2000. The start of static structural testing was significantly delayed due to flaperon repairs. Also, the failure of the static test fixture, housing the test vehicle, at 141 percent of design limit load will further delay static testing to 150 percent of design ultimate load. However, static testing to 141 percent design limit load will support Aircraft 4003 clean envelope expansion, thereby meeting the LRIP DAB exit criterion. Approximately

one and one-half months are required to redesign and change the material of the failed fixture component.

Delays in static testing also impacted the initiation of fatigue testing from the original scheduled start in early 2000 to actual start on December 21, 2000. The applicable LRIP DAB exit criterion, established in December 1999, is initiation of fatigue testing with a goal of 40 percent of first life complete by the end of 2000. While the LRIP DAB exit criterion was met, the goal was not since only about one percent of the first life has been accomplished. Although this fatigue testing does not impact expansion of the allowable flight envelope, completion of the first fatigue life does affect the point at which structural changes, necessitated by the results of fatigue testing, can be installed into the production line.

LFT&E activities in 2000 have focused on pre-test analysis and test planning for fuel tank hydrodynamic ram damage tests. Test planning and pre-test evaluation were performed for upcoming tests on a replica of the fuselage fuel tank and Aircraft 4001 wing scheduled for FY01. The Air Force conducted hydrodynamic ram analyses of the fuselage fuel tank to identify appropriate shotlines. A shotline was selected which will provide data to evaluate fuselage fuel tank hydrodynamic ram damage and its affect on safe operation of the crew escape system. A change in threat projectile for this test has required a re-evaluation of the pre-test predictions. Analyses were also conducted in support of LFT&E to assist shotline selection for the upcoming wing hydrodynamic ram test. A shotline was selected and detailed wing hydrodynamic ram damage analyses are being conducted to predict results of the test, which will be performed on Aircraft 4001.

Engine testing remains on schedule to support the flight test program through the end of EMD. The LRIP DAB exit criterion "Complete first portion of engine Initial Service Release (ISR) qualification test (2150 TACs - full hot section life)" was completed on Flight Test Engine (FTE) #18 on November 3, 2000. The complete ISR qualification test of 4325 Tactical Accelerated Cycles (TACs) is expected to be completed before the end of 2001. Based on this nearly-on-schedule test performance, engine deliveries to support the two PRTV I aircraft (Aircraft 4010 and Aircraft 4011) for IOT&E support should not be a problem. The F119 engine performance and reliability in the three F-22 flight test aircraft have been the highlight of the F-22 flight test program. There has not been an engine-caused failure to complete a scheduled test condition. In addition, there has not been an engine-related shutdown to this point in the test program, although there have been two precautionary shutdowns due to indications of Airframe Mounted Accessory Drive (AMAD) and generator problems.

In addition to flight testing at Edwards AFB, logistics testing tasks including initial low observability maintainability tasks are ongoing using low observable test articles and exercising aircraft access doors. The basic F-22 design has some good improvements in terms of minimizing the number of access doors in their design. High reliability is also essential to minimizing access requirements and the attendant low observable restoration procedures. The brush and roll repair process has been developed and should reduce repair risk. The concept for low observable sustainment and how to test it are issues yet to be addressed. Although new materials and techniques have been developed, the plan does not include demonstrating the ability to sustain operations in adverse conditions. In addition, operational field measurement capability has not been fully addressed; plans are to rely solely on maintainer adherence to technical data. Completion of logistics test tasks proceeded throughout this year but were severely constrained by the lack of flight test vehicles with avionics sub-systems.

TEST & EVALUATION ASSESSMENT

The F-22 flight test program has fallen considerably behind schedule during the last year. Although some of the necessary test support activities, such as the Flying Test Bed (FTB) and Avionics Integration Lab (AIL), have been making progress in supporting the test program, the flight testing at Edwards AFB has not met the beginning of the year 2000 projections. As of January 3, 2001, flight test aircraft have only accumulated 324 hours of the 590 hours planned just one year ago. Although Aircraft 4003 was delivered to Edwards AFB on March 15, 2000, it did not begin productive flight testing until September 19, 2000, due to an extended lay-up for structural modifications and instrumentation calibrations. Aircraft 4003 is the first flight test aircraft to incorporate the extensive structural modifications identified as Block II structure, which is the production-representative structural configuration required to expand the permissible flight envelope. This aircraft must, however, complete selective regression testing of the envelope explored by Aircraft 4001 and Aircraft 4002 before it can start to expand beyond these limited flight envelope boundaries. As of January 10, 2001, Aircraft 4003 has only flown for 31.9 hours.

Since January 2000, various problems have caused program delays and occasional flight test stoppages. Test flying was constrained primarily by late delivery of aircraft, canopy transparency cracks, aileron hinge pin problems, flaperon repairs, environmental control system problems, and inlet delamination inspections. As a result of these delays, only about 40 percent of the projected test points have been completed.

Analysis shows that late deliveries of avionics flight test Aircraft 4004 through 4009 requires 8.6 additional months to complete the currently planned 1,970, from the original 2,270, avionics flight test hours. Without any adjustments to the program schedule, the F-22 System Program Office (SPO) estimates that approximately 150 flight hours of planned airframe development testing and about 17 aircraft months of required avionics testing would not be completed by the start of IOT&E. Although some limited airframe and avionics development testing could be accomplished in parallel with IOT&E, there are other required test events that must be completed before start of IOT&E. Also, the scheduling and availability of test assets and resources would limit the scope of any parallel test operations.

The current status of the test program and the SPO schedule estimates show that the planned test program cannot be completed as originally scheduled and that IOT&E cannot be started in August 2002 without clearly unacceptable risks. On December 20, 2000, the Air Force briefed DOT&E with a plan that would defer the start of IOT&E by four to six months allowing additional time to complete the required developmental testing. Although as much as nine months to a year delay may be needed to complete required testing, DOT&E strongly supports the plan.

Weapons internal carriage provides the F-22 with lethal capabilities while maintaining low observability. The integration of avionics and weapons systems to launch precision weapons is a major step in the flight test program for validation of the software block algorithms. These software block algorithms are also necessary for the mission-level simulation in the air combat simulator (ACS) during pilot training and mission-level IOT&E sorties. The completion of three exit criterion, "Initiate high angle-of-attack testing with weapons bay doors open," "Initiate separation testing of AIM-9 missile," and "Initiate separation testing of AIM-120 missile" demonstrated the initial test tasks in weapons employment. To date, the flight test program has demonstrated unguided launch of an AIM-9M Sidewinder from the side weapons bay on July 25, 2000, and an unguided launch of an AIM-120 from the main weapon bay on October 14, 2000, from Aircraft 4002. High angle-of-attack testing with the main and side weapons bay doors open began on August 22, 2000. This testing was accomplished relatively easily, further demonstrating the F-22's outstanding high angle of attack flying qualities.

Flight test validation of the software block necessary for the start of IOT&E pilot upgrade training is critical. The SPO proposed parallel developmental test (DT) sorties during IOT&E should be a DAE review topic to better understand the impact on the EMD schedule. In addition, we are concerned about the deferral of the external weapons/stores flight testing to the Seek Eagle Program, currently planned for FOT&E in 2003 at the earliest. It would be better to do this external carriage testing earlier to identify the aerodynamic impact of external stores, so that any issues could be resolved much sooner.

Completion of static structural testing without any major failures is an important prerequisite for expanding the allowable flight envelope by Aircraft 4003, justifying its selection as an LRIP DAB exit criterion. This has been achieved with only one of 19 major tests left to complete. The initiation of the first fatigue life with a goal of 40 percent of first life is another LRIP DAB exit criterion. Fatigue testing started on December 21, 2000, but only about one percent of the first life has been accomplished. Although this fatigue testing does not directly impact flight envelope expansion, completion of the first fatigue life does affect the point at which structural changes necessitated by fatigue test failures can be inserted in the production line and possible retrofit requirements.

Low observable measurement and maintainability continues to be a risk area, based on previous low observable platforms. This risk category includes reliability and logistics support. The concept for low observable sustainment and how to test it is an issue, not only to validate the new materials and repair techniques, but also to validate the low observable specifications as measured during full-scale pole and chamber testing. All available measurement tools, including ground, air, and range, should be utilized in this validation process. RCS flight testing has not yet begun. The baseline plan showed that this would be conducted in mid-2000 on an outdoor test range after RCS mapping in the Lockheed Martin RCS Measurement Facility in Marietta, GA. However, late aircraft delivery plus RCS impacts from an inflight main landing gear door gap problem and weather delayed open-air range testing. The aircraft went through extensive surface preparations and painting in preparation for this inflight RCS measurement testing. RCS measurement with an alternate inflight air-to-air imaging system was used to spot certain low observability features, but this did not meet the requirement to measure full aircraft RCS at a calibrated range. After Aircraft 4004 is ferried to Edwards AFB, it will complete the final portion of the exit criteria with a flight across a calibrated range.

Early LFT&E of wing hydrodynamic ram effects resulted in a redesign that will be tested using flight test Aircraft 4001. Changes to the wing design included addition of titanium wing spars, an additional wing rib, and additional wing skin fasteners. If successfully demonstrated, the wing redesign will significantly decrease F-22 vulnerability.

The results of the dry bay Live Fire Tests indicate that both MLG and AMAD bays, which lack an onboard fire protection system, pose significant vulnerabilities that could be significantly reduced or even eliminated. Preliminary data show that an effective fire suppression system could be developed using either pentafluoroethane (HFC-125), solid propellant gas generating technologies or other approaches. However, a programmatic decision was made by the Air Force to forgo development of fire extinguishing systems for MLG bay. An onboard fire protection system for the AMAD was not included in the aircraft design. Live Fire Testing has shown that the overall vulnerability had been underestimated. Once the vulnerability models used to estimate the overall vulnerability were updated using the test results, there was a significant increase in F-22 vulnerability. The Air Force relaxed the estimates of F-22 vulnerability requirement by about 30 percent to accommodate increases in the estimated vulnerability since January 1995. The current design meets the new relaxed design specification for vulnerability. Since no significant design changes are expected, additional changes to the vulnerability specification are not anticipated. The overall vulnerability of the current design may change depending on the outcome of the remaining Live Fire Tests.

AFOTEC has initiated a five-year Operational Assessment with periodic briefings and a report, based on a structured strategy-to-task assessment of all F-22 mission tasks, to support the Readiness to Test Certification of IOT&E. AFOTEC identified both positive highlights and potential issues during the interim briefing of operational results this year. The current results were based on bench, lab, and flying test bed data, which supplemented flight test data and extensive participation on the integrated product teams. Performance concerns included risk to avionics integration progress, development of low observable maintenance concept of operations, flight envelope expansion considerations related to structural adequacy analysis, ground handling, cockpit design, security issues, possible operational training constraints, and future performance of the environmental control system. Test and evaluation concerns included consistency of production representation among the operational test aircraft, flight envelope expansion for operational test pilot training, and air-to-air range infrastructure data processing timeline and data display capability for the primary test organization. Since an AFOTEC test pilot and several maintenance personnel are members of the F-22 combined test force, AFOTEC has first-hand knowledge of potential operational problems, thus able to contribute to timely solutions.

LESSONS LEARNED

A lesson can be learned from the deletion of the ECS simulator as a cost-saving measure. This decision contributed to the delay of the Aircraft 4004 first flight by at least two months and may indirectly result in further delays to the remaining avionics-equipped test aircraft.

The original LFT&E strategy called for manufacturing a production-representative wing for the hydrodynamic ram test. The Air Force has decided to use flight test Aircraft 4001 for this test as a more economical alternative. Using the flight test vehicle, in addition to economic savings, will provide a more realistic test article. This use of early flight test vehicles to address LFT&E issues should be an option considered in future programs. LFT&E results thus far have shown that dry bay fires do occur but are not predicted well by current modeling and simulation (M&S). Additional M&S effort is required to develop an adequate methodology for predicting dry bay fires, taking into account all independent variables. DOT&E recommends that the Air Force reconsider its decision to eliminate the fire suppression system for the MLG bay as well as consider adding AMAD bay fire protection.

CONCLUSIONS AND RECOMMENDATIONS

As I have stated the last two years in testimony before the Senate Armed Services Committee, AirLand Forces Subcommittee, programmatic efforts to reduce costs to stay within the cost cap almost always result in less testing and increased development risks. These development risks become greater with elapsed time as the cost reduction options become harder to implement. At this point, since the test budget is essentially the only remaining uncommitted EMD budget, cost reductions become test reductions. Any reduction of testing tasks increases the risk of not being ready to start or successfully complete IOT&E.

